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## **Special Issue – Product Design and Engineering**

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## EDITORIAL

### Special Issue – Product Design and Engineering

This special issue of *Chemical Engineering Research and Design* (ChERD) is devoted to the ‘emerging’ discipline of (Chemical) Product Design and Engineering.

Chemical engineers, chemists and application developers employed in the area of product development might ask whether product design and engineering indeed is a new discipline within the field of chemical engineering. In a sceptical mood they might even ask for a definition of product technology and certainly will claim that it already is an existing activity within the R&D and manufacturing departments of companies that produce structured products. Pharmaceuticals, agrochemicals, cosmetics, detergents, adhesives, coatings or food-based consumer products are just a few examples of products that have been designed and engineered, to fulfill user requirements. Nevertheless, many workers in these sectors of the chemical process – product industry, i.e. researchers, developers and producers, as well as academics believe that product design and engineering should be developed and taught as a new branch of chemical engineering. The justification for this viewpoint can be extracted from the series of articles covered in this issue. The presented papers suggest that the discipline of ‘Product Technology’ covers a wide range of scientific skills, a multitude of processing tools and a rather diverse group of structured products.

The paper by Voncken *et al.* presents an overview of the many aspects of product technology against the backdrop of historic developments in the chemical engineering sciences and its application to manufacture bulk specification products. This part of the chemical sector has matured to a state in which the reduction of production-cost drives technology improvements and plant production capacities, and the business recently has undergone significant consolidation and cost-reduction exercises. Despite the overwhelming size of these specification-products businesses, most of its output reaches end-use consumers as formulated and structured products. The paper highlights the importance of such structured products in our current society, the need to shorten the ‘time to market’ for new products, and above all, the need to design products to fulfill specific consumer requirements. It defines product technology (product design and engineering) as a multidisciplinary approach to add value to materials by improving and designing new products. The authors state that many disciplines are needed in this design process that starts with the definition of product performance requirements, followed by an iterative sequence consisting of material selection, formulation, processing, production and, ultimately, marketing the product. The paper is an interesting introduction to the complexity of chemical product design, it offers an overview of the breadth of the discipline, and it stresses

the need to adapt chemical engineering curricula to better prepare students for positions in this part of the special-products industry. Still a number of challenges have to be met and the authors promise to cover topics such as ‘product technology generics’, ‘process-product relations’ and the definition of performance in a subsequent paper.

A first view on the generics of product technology follows from the other papers in this issue. They illustrate not only the breadth of the discipline, but also introduce the reader to the many different dimensions and the fundamental sciences required in the design of a product. Let’s consider the product design and development path starting with material selection, leading through formulation development, formulation processing, and finally the shaping of the performance consumer product, as the first set of dimensions. Each step in this sequence involves the application of physical and chemical sciences both at micro- and macro-level. Considering the sequence from the material selection end, not only an understanding of the relationship between molecular structure and product properties for a single component seems important, but also the interaction between components within the structured product needs to be considered. In the processing and shaping stage, the influence of molecular structure on the processing behaviour has to be considered and, inversely, the type of processing and the conditions applied during processing may affect the molecular characteristics. Looking towards the other end of the development sequence, the processing of the materials largely determines the structure of the product and therefore also determines a considerable portion of the ultimate performance properties.

Different product areas and different product industries may be considered as yet another dimension. Products resulting from the above sequence are used in different application areas, have different functions and serve different markets. Nevertheless, the design and development rules and the management of product development projects are expected to be the same for different products and different markets. This leads to the initial conclusion that the product technology discipline should be built on a broad coverage and combination of chemical and physical sciences, engineering sciences and management sciences.

As such, some of the presented papers focus on the application of chemistry to obtain the desired product and it may be placed towards the material selection side of the development sequence. A first example illustrating the blending of different chemical disciplines is shown in the paper on the production of polystyrene composites reinforced with natural fibres. It is an example of the growing interest in the manufacture of hybrid composites based on synthetic thermoplastics reinforced with renewable

natural fillers and fibres. Vilaseca *et al.*, illustrate that chemical modification of the natural reinforcements enhances its anchoring and adhesion into the synthetic polymer matrix. As such, the work on these composites shows that instead of using classical reinforcing media like glass-fibre, the marriage of organic chemistry, polymer chemistry, interfacial chemistry and polymer processing offers a way to 'engineer' mechanical properties into this new class of hybrid composites.

Other papers focus on the middle section of the development sequence, i.e. the use of processing technology to obtain the desired product properties. In particular, particle generation and control over particle properties are areas that receive a lot of attention, both in practice and theory. A number of papers discuss different routes to manufacture nanoparticles. By applying basic transportation phenomena, a theoretical basis has been developed for the manufacture of stable and homogeneously distributed vitamin E particles for beverage applications. Chen and Wagner subsequently produced the product by nanoparticle homogenization (mechanical processing) technology and particle stabilization using starch micro-encapsulation technology. Dagaonkar *et al.* on the other hand applied the physicochemical characteristics of micellar water-surfactant systems to produce nano-sized calcium carbonate through the carbonation of lime solutions in reverse micellar systems.

Yet another technology to produce nano-sized particles is presented by Johannessen *et al.* They describe the synthesis of catalyst particles in flames and describe that the technology can be used as a product/process engineering tool for other applications. The paper by Bröckel and Hahn discusses the design of 'smart' fertilizer particles offering a controlled release of mineral nutrients to the plants when needed. In particular, surface treatment and/or coating techniques offer ways to obtain the required performance characteristics. To better understand particle formation and dissolution, Štěpánek developed computing tools that simulate the morphology and behaviour of particles during granulation and dissolution.

Finally, a number of papers discuss recent experience in teaching product technology, the management of product design and production layout, and the development of computing tools to assist designers. Both Shaw *et al.* and Saraiva and Costa describe their experience of teaching

chemical product design. Both groups stress the benefits for teams of chemical engineering students as they work through the technical and managerial aspects of hands-on product development examples. A paper by Van Donk and Gaalman focuses on the business and production design aspects for new products, with particular focus on the production engineering and design for food processing companies that face a large number of product changes.

From the above it should be clear that chemical product designers and developers have a large number of decisions to make during the product design phase. First of all, decisions have to be made about the priority setting of the desired product requirements. Usually, not all requirements can be fulfilled, nor are they all critical to make a quality product. Next, decisions have to be made on the chemical and/or physical approaches to design and manufacture of a desired product. Last but not least, product economics has to be considered. In his paper, Gani describes computing tools developed to assist designers to choose the correct pathways through the large space of alternatives. These tools are expected to mature as product technology evolves as a new discipline.

Still a lot of work has to be done to develop a generally applicable chemical product design and engineering framework. The generics of the discipline will become clearer over time, but also the application of fundamental sciences and modelling capabilities known for simple product systems will develop into capabilities that can be applied in the sometimes very complicated structured products we may wish to design. As an example, Abildskov and Kontogeorgis present a paper that highlights the challenges in the area of thermodynamic modelling of complex multi-component multiphase systems.

In conclusion, this issue of ChERD presents many aspects of Product Design and Engineering (Product Technology) that are expected to develop over the next couple of years. We should be looking forward to future issues covering this topic.

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